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A RECONNAISSANCE SPACE SENSING INVESTIGATION OF CRUSTAL STRUCTURE FOR A STRIP FROM THE EASTERN SIERRA NEVADA TO THE COLORADO PLATEAU

Argus Exploration Company
555 South Flower Street - Suite 3670
Los Angeles, California 90071

January 1974
Interim Report for period: 1 July - 31 December 1973

Prepared for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

E74-10207) A RECONNAISSANCE SPACE SENSING INVESTIGATION OF CRUSTAL STRUCTURE FOR A STRIP FROM THE EASTERN SIERRA NEVADA TO (Argus Exploration Co., Los Angeles, Calif.) 26 p HC $3.50 CSCL 08E G3/13

N74-15015

Unclas
00207

Approved by

W. E. Hosken

W. E. Hosken, President

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.

4. Title and Subtitle: A Reconnaissance Space Sensing Investigation of Crustal Structure for a Strip from the Eastern Sierra Nevada to the Colorado Plateau

5. Report Date: January 1974

6.

7. Author(s): Mark A. Liggett and Staff

8. Performing Organization Rept. No.

9. Performing Organization Name and Address:
Argus Exploration Company
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10. Project/Task/Work Unit No.

11. Contract/Grant No.: NAS5-21809

12. Sponsoring Organization Name and Address:
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

13. Type of Report & Period Covered: Type II Progress Report
1 July - 31 Dec. 1973

14.

15. Supplementary Notes

16. Abstracts: This report summarizes research progress in an investigation using ERTS-1 MSS imagery to study regional tectonics and related natural resources. Field reconnaissance guided by analysis of ERTS-1 imagery has resulted in development of a tectonic model relating strike-slip faulting to crustal extension in the southern Basin Range Province. The tectonics of the northern Death Valley-Furnace Creek Fault Zone and spacially associated volcanism and mercury mineralization were also investigated. Field work in the southern Sierra Nevada has confirmed the existence of faults and diabase dike swarms aligned along several major lineaments first recognized in ERTS-1 imagery. Various image enhancement and analysis techniques employed in the study of ERTS-1 data are summarized.

17. Key Words and Document Analysis. 17a. Descriptors
Tectonics
Geology
Basin Range Province
ERTS-1 Satellite imagery

17b. Identifiers/Open-Ended Terms
Mineral exploration
Geologic hazards

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages
Release unlimited	20. Security Class (This Page) UNCLASSIFIED	22. Price

PREFACE

The following report summarizes research conducted in geologic applications of data from the Earth Resources Technology Satellite (ERTS-1) for the period from 1 July to 31 December 1973. During this period, most geologic field investigations were completed, and emphasis has been shifted to regional syntheses of tectonic interpretation, and evaluation of practical research applications.

The following objectives summarize the scope of this investigation:

A. Analysis, interpretation and evaluation of ERTS-1 data for application to the study of regional crustal structure and related geologic phenomena.

B. Comparison and evaluation of selected available remote sensing techniques, including Apollo-9, X-15 and U-2 photography, SLAR, and multispectral imagery.

C. Conducting of field investigations to support imagery interpretation and to evaluate potential applications to natural resource exploration and management.

Results of investigation summarized in this report support the following conclusions:

1. The scale, resolution and spectral range of the ERTS-1 MSS imagery permits interpretation of structural alignments over larger areas than feasible with conventional aerial imagery or geologic mapping. The synoptic nature of the ERTS data provides an effective filter for recognition of regional geologic features, trends or patterns obscured by detail at the scale of an outcrop or quadrangle map.

2. The ability to interpret regional structural patterns and geologic correlations from ERTS-1 data establishes a basis for integration and synthesis of independent data, previously possible only with map compilations. Results of our research document the value of ERTS-1 data in studying the interrelationships of regional structure and volcanism, plutonism and related alteration, mineralization, and geothermal activity.

3. Field reconnaissance guided by ERTS-1 imagery is highly efficient, especially when aided by subsidiary remote sensing data of intermediate scale and resolution. Although anomalies in the ERTS imagery frequently have vague expression in the field, critical sites for detailed mapping or geophysical study can be determined, eliminating extensive ground-based reconnaissance required in conventional quadrangle mapping. This speed and efficiency are highly valuable in practical applications to mineral and hydrologic exploration and study of geologic hazards.

I. INTRODUCTION

The following report summarizes results of research on geologic applications of data from the Earth Resources Technology Satellite (ERTS-1). This investigation was conceived to test the use of orbital remote sensing in the study of regional structural geology and related applications to resource exploration and management. It is based on a background in remote sensing applications to mineral exploration, and study of tectonic controls of ore genesis and distribution.

The area chosen for investigation occupies an area of over 70,000 square miles in the southern Basin Range Province of eastern California, southern Nevada, southwestern Utah, and northwestern Arizona. A map of the test site is shown in Figure 1. The site spans diverse geology from the Sierra Nevada batholith, across the block faulted Basin Range Province, to the sedimentary terrain of the Colorado Plateau. The variation in geology across this region is similar to mountain belts of several other continents. Although it is within these mountain belts that most of the world's mineral resources have been recovered, their tectonic evolution is poorly understood. Better understanding of regional geology will have an important role in exploration for future resources.

In this investigation, analysis and interpretation of ERTS-1 imagery is being coordinated with a variety of other remote sensing data. These include NIMBUS infrared imagery, Apollo-9 photography, NASA-USAF X-15 photography, NASA and USAF U-2 photography, and Side Looking Aerial Radar (SLAR). This comparison of data over key test sites was intended to provide a basis for evaluating applications of different sensing techniques.

Much of the geologic information contained in the ERTS-1 data is extracted with the aid of image enhancement and analysis tools. We are investigating and experimenting with a variety of photographic, optical, and electronic enhancement technqiues.

Analysis and interpretation of the ERTS-1 and subsidiary remote sensing data is supported by an extensive program of geologic field reconnaissance and geologic mapping. This ground truth permits identification of geologic causes of data anomalies, and provides a basis for refinement of image interpretation techniques. Special attention is placed on correlations of tectonic patterns to other geologic phenomena, including ages, types and distribution of plutonic and volcanic centers, known mineral deposits, known geothermal sources and recorded earthquake epicenters.

This progress report summarizes progress in each of the many disciplines coordinated in the overall investigation. We are confident from research results that analysis and interpretation methods being developed in this investigation will extend application of ERTS-1 data to other areas in the world where regional structural reconnaissance, either by air or on the ground, has not been possible.

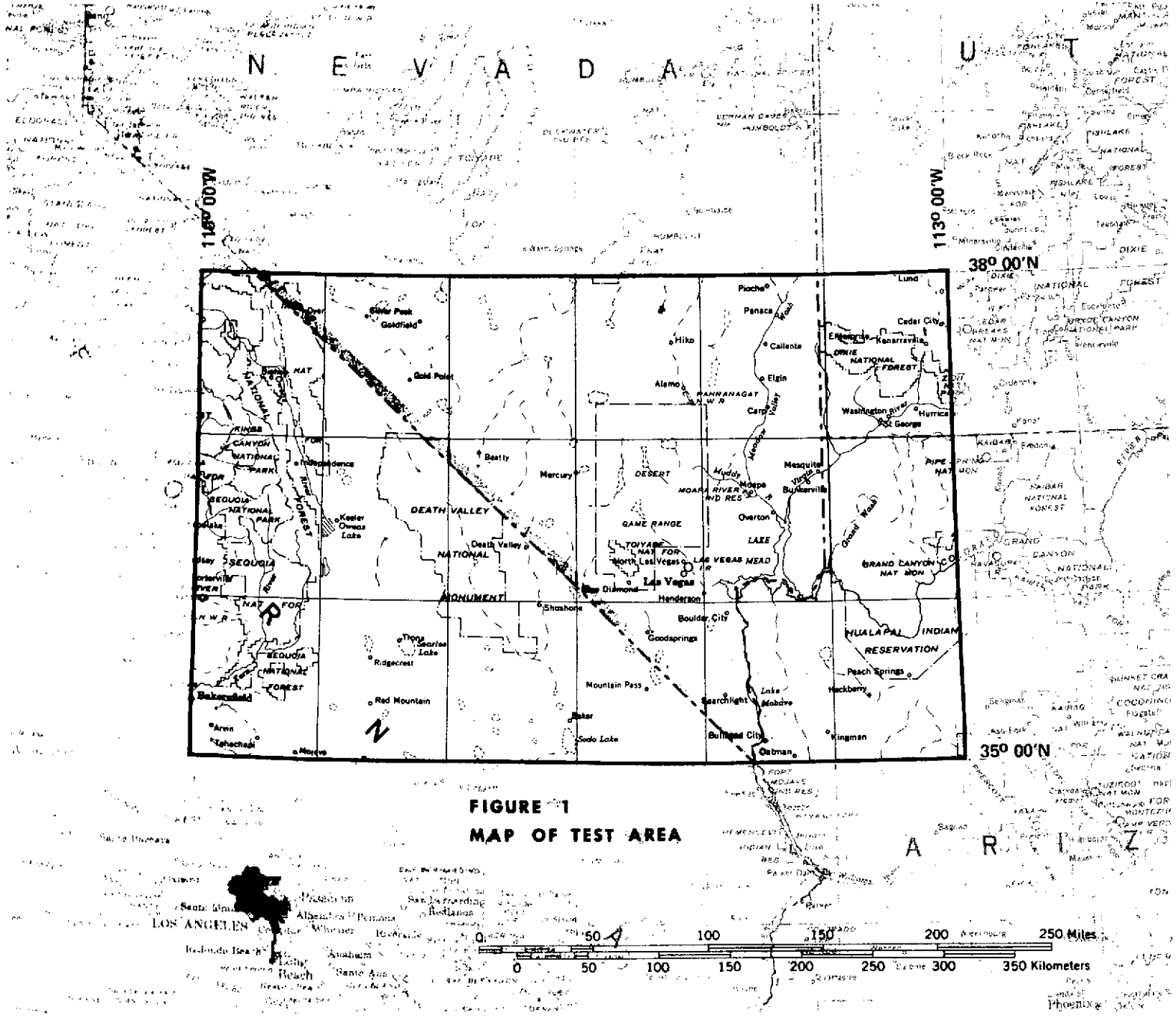

FIGURE 1
MAP OF TEST AREA

II. RESEARCH SUPPORT

A. Scientific Staff and Technical Personnel:

The following personnel were assigned to the research staff during the six month period of this report:

Scientific Staff

Mark A. Liggett, Field Geologist and acting Principal Investigator

John F. Childs, Field Geologist

Helmut E. Ehrenspeck, Assistant Geologist

Technical Aids

Jack W. Barth, Research Assistant

Alex Costa, Research Assistant

Richard L. Hutchens, Technician and Field Assistant

Backup Personnel (covered in G & A)

Secretary

Clerk-typist

Accountant

B. Data Handling

Organization and handling of NASA data has required design of indexing and filing systems for ERTS-1 prints, negatives, transparencies, and color composites, and subsidiary imagery including NIMBUS, X-15, NASA and USAF U-2 photography, and SLAR. These indexes form an important reference tool for support of ground-based geologic reconnaissance and data interpretation. A comprehensive data handling and analysis plan was submitted to Goddard Space Flight Center on 4 December 1972. Procedures outlined in this plan are currently in effect.

C. Data Research

Search for available published and unpublished geologic, geophysical and remote sensing data over the ERTS-1 test area is conducted as an integral part of research. This task has included plotting of imagery, and multiple reference indexing of relevant reports and maps. During this reporting period, data has been researched through the following sources:

Earth Resources Research Data Facility, NASA-JSC, Houston, Texas
U. S. Geological Survey, Menlo Park, California
Nevada Bureau of Mines, Reno, Nevada
Office of Arid Lands Studies, University of Arizona, Tucson, Arizona
WESRAC, University of Southern California, Los Angeles, California
University of California, Los Angeles, California
Pomona College, Claremont, California
Space Science & Engineering Center, University of Wisconsin, Madison, Wis.
Review of current scientific literature, journals and proceedings
Miscellaneous personal communication and correspondence.

D. Scientific Communications and Correspondence

Communication has been maintained on scientific progress and project administration with our principal NASA contract monitors.

Dr. Paul D. Lowman, Jr., Scientific Monitor
Mr. Edward W. Crump, Technical Monitor
Mr. Douglas Frye, Contract Specialist

A comprehensive technical review of research status was conducted in a meeting between Mark Liggett and NASA monitors P. D. Lowman, Jr. and E. W. Crump at Goddard Space Flight Center on 20 July 1973. In addition, Argus Exploration was represented by Mark Liggett at the NASA Geology Panel review meeting held at Goddard Space Flight Center on 27 October 1973. Mark Liggett and John Childs attended the Third ERTS Symposium in Washington, D. C., 10-14 December 1973.

In order to facilitate acquisition and dissemination of information, we have conducted correspondence or discussions with other investigators in research relating to the ERTS-1 program. As appropriate, this correspondence has involved exchange of data, analytical and interpretation methods and applications. Correspondents in these categories include:

Dr. A. K. Baird, Pomona College, Claremont, California

Mr. John E. Carlson, U. S. Geological Survey, Menlo Park, California.

Dr. David Cummings, Department of Geology, Occidental College, Los Angeles, California.

Dr. K. Ebtehadj, Dr. M. Akhavi and Mr. A. Ghazi, Plan and Budget Organization, Imperial Government of Iran, Tehran, Iran.

Dr. Richard Fiske, U.S. Geological Survey, Washington, D.C.

Mr. Robert Fox, Consulting Engineering Geologist, Fullerton, California.

Dr. Alexander Goetz, Jet Propulsion Laboratory, Pasadena, California.

Mr. Rogers Johnson, Department of Earth Sciences, University of California, Santa Cruz, California.

Mr. Michael Kennedy, Geologist, California Division of Mines and Geology, Los Angeles, California.

Mr. C.A. Lehnertz, Jr., Phelps Dodge Corporation, Littleton, Colorado.

Dr. Floyd Sabins, Chevron Research Corp., La Habra, California.

Dr. Rushdi Said, Director, Geological Survey of Egypt, Cairo, Egypt.

Dr. O.T. Tobisch, University of California, Santa Cruz, California.

Dr. D.T. Vaniman, Geological Survey of Nigeria, Kaduna, presently at University of California, Santa Cruz, California.

Dr. A. Volborth, Dalhousie University, Halifax, Nova Scotia.

Mr. E.A. Winter, Phelps Dodge Corporation, Boulder City, Nevada.

E. NASA Data Requests

Standing Order

No changes have been made in our Standing Order Form of 18 October 1972. Routine ERTS-1 MSS coverage was terminated as of July 1973 as originally proposed.

Retrospective Requests

The following retrospective requests were made to NASA Data Banks for subsidiary data in support of our ERTS-1 investigation:

10 August 1973: Retrospective request for ERTS-1 MSS Frame #1069-17434 9.5 inch positive transparencies for Bands 4-7.

10 September 1973: Retrospective request for ERTS-1 MSS Frame #1032-17373 and #1069-17432 9.5 inch positive transparencies for Bands 4-7.

III. SUMMARY OF INVESTIGATION

A. Sensor Comparison and Evaluation

A variety of remote sensing data has been used in conjunction with ERTS-1 imagery for geologic analysis and interpretation. This data has been coordinated with field reconnaissance, and has proved to be an important complement to the ERTS-1 MSS imagery. In many instances, access to a variety of data over key field areas has provided information not apparent by any single remote sensing technique. The subsidiary remote sensing data used in our investigations during this reporting period include:

1. NIMBUS HRIR imagery.
2. Apollo-9 Ektachrome photography.
3. X-15 color IR and panchromatic black and white photography.
4. NASA U-2 color IR and multispectral photography.
5. U.S.A.F. U-2 panchromatic black and white photography.
6. Side-looking aerial radar.
7. Conventional low altitude panchromatic black and white aerial photography.
8. Hand held aerial reconnaissance photography, Ektachrome and color IR.

Within this reporting period, applications of subsidiary remote sensing data have supported the evaluations discussed in the Argus Exploration Company Type II Interim Report of July 1973. The reader is referred to this earlier report for more detail.

B. Image Enhancement and Analysis Techniques

A variety of image processing and enhancement techniques have been employed in analysis of ERTS-1 MSS imagery and subsidiary remote sensing data. These include several photographic, optical, and digital computer processing techniques discussed in detail in the Argus Exploration Company Type II Interim Report of June 1973. These techniques include:

1. Additive color viewing.
2. Multispectral color compositing

3. Dye transfer color printing.

4. Edge enhancement processing.

5. Optical Fourier transform analysis.

6. Directional pattern analysis using Moire patterns.

Standard data reproduction techniques are discussed in the Type II report of 19 January 1973, and will not be reviewed here.

During the current reporting period, emphasis in image processing has been placed on color photographic enhancement of multispectral imagery. A Report of Investigation was submitted in November, outlining an operational laboratory procedure for producing high resolution false color composites:

False Color Compositing of ERTS-1 MSS Imagery
By: Wally MacGalliard and Mark Liggett
Report of Investigation, November 1973

Spectral Ratioing

Research and experimentation has been conducted on photographic techniques for false color compositing of ERTS-1 MSS band ratio images. The ratio images are produced using photographic masking techniques which approximate the mathematical ratio of film densities between two chosen MSS bands. This is done by making a set of properly contrast balanced positive and negative transparencies of the various MSS bands. A registered sandwich is assembled which consists of a positive and negative transparency of the two desired MSS bands. This sandwich is then used to expose a high gamma film transparency to produce a photographic ratio image.

For example, a sandwich consisting of a negative transparency of MSS #5 and a properly balanced transparency of MSS #4 will produce a positive ratio image which we designate as R5/4.

Three such ratio images were produced using the following MSS bands:

1. R5/4 representing MSS #5 divided by MSS#4.

2. R7/5 representing MSS#7 divided by MSS#5.

3. R4/7 representing MSS#4 divided by MSS#7.

These three black and white ratio images were then combined in a false color composite using the technique for high resolution false color compositing described by MacGalliard and Liggett (November 1973).

Preliminary results of this investigation show promise in facilitating the use of ERTS-1 MSS imagery for discrimination of rock and soil types, analysis of vegetation distribution, and related geologic applications. Additional experimentation is planned as permitted by time.

The principles of spectral ratioing as an image enhancement and analysis tool have been documented in extensive investigations by Alexander Goetz and Fred Billingsley of the Jet Propulsion Laboratory, Pasadena, California. Our experiments in this field are built upon this pioneering research.

C. Summary of Field Work

Field work conducted during this reporting period has involved regional reconnaissance as well as detailed studies of key areas in the test area. Some of these studies are presented as significant results in a separate section of this report and the reader is referred there for more comprehensive discussion:

Sierra Nevada, California

Field reconnaissance has been conducted along lineaments recognized in ERTS-1 MSS imagery over the southern Sierra Nevada between the Kern River and Owens Valley, Kern and Tulare Counties. The lineaments are expressed in the ERTS-1 imagery as alignments of linear valleys, ridges and other topographic features. Field mapping has indicated consistently poor outcrop exposure along lineaments and ambiguous evidence for their causes. The most consistent associations of features aligned along lineaments are found to be diabase dikes, cataclastic foliation and shearing. A radiometric age date analysis was performed on a specimen of diabase dike rock in order to determine its age relative to other geologic features in the area. The lineaments are believed to represent zones of crustal weakness reactivated in several orogenic episodes since middle Cretaceous time. These zones are expressed topographically as a result of weathering and erosion. A report of Investigation is in preparation.

Lincoln County, Nevada

Field work, guided by ERTS-1 data, was conducted in the region between the southern Pahroc Range and the Delamar Mountains, Lincoln County, Nevada. The work was undertaken in an attempt to understand the relationship of Basin Range faulting to a local zone strike-slip displacement, called the Pahranagat Shear System.

Field work in the area near Delamar Lake supports the interpretation of left-lateral strike-slip movement along several northeast trending faults. This strike-slip deformation does not continue northeastward into the Delamar Mountains beyond Gregerson Basin and is believed to be contemporaneous with late Tertiary range-front faulting. A structural model has been developed which suggests that the Pahranagat Shear System formed as a transform fault separating two areas of crustal extension. A Report of Investigation accompanies this progress report.

Fish Lake Valley, Nevada

ERTS-1 structural anomalies have been investigated in a rhyolitic to basaltic volcanic terrain at the northern end of Fish Lake Valley, Nevada. This field work has established that the Death Valley-Furnace Creek Fault Zone cuts the southern part of a volcanic sequence along the east side of the White Mountains but does not continue northward as a distinct fault zone. Rather, the fault pattern changes northward to a complex series of normal and strike-slip faults within the volcanics and this pattern in turn terminates against an east-northeast trending fault zone of possible left-lateral displacement. No evidence was found to indicate that the Death Valley-Furnace Creek Fault Zone extends north of this east-northeast trending zone.

Known mercury mineralization is associated with the faults in the volcanics near the termination of the Death Valley-Furnace Creek Fault Zone. A Report of Investigation on this research accompanies this report.

Tonopah to Goldfield, Nevada

Field reconnaissance of linear anomalies in ERTS-1 MSS imagery has revealed several large normal fault zones trending roughly north-south in the area west of Tonopah and Goldfield, Nevada. The most prominent of these features extends southward for approximately 35 miles between Paymaster Canyon and Lida Wash. The Paymaster Canyon-Lida Wash Fault is a west dipping normal fault which terminates abruptly on the south against a complex east-west structural zone in the Palmetto Mountains. Large normal faults east of the Paymaster Canyon-Lida Wash Fault also appear to terminate southward against the east-west zone. Field work southwest of Goldfield, Nevada has shown that many of these normal faults displace rocks of Paleozoic Age as well as the overlying Tertiary volcanic cover. This relationship has not been shown on previous geologic maps of the area. The north-south and the east-west trending faults studied in this region are the two most conspicuous structural trends visible in ERTS-1 imagery in the area immediately east of the Death Valley-Furnace Creek Fault.

Fixed-wing aerial reconnaissance was conducted in support of field work in this area. During aircraft overflight, 35 mm Ektachrome and Ektachrome Infrared photographs were taken for comparison with ERTS-1 MSS false-color composites. A report on a previously unreported normal fault zone in the Paymaster Canyon - Lida Wash area was included in the Argus Exploration Company Type I Progress Report of 9 November 1973.

Regional Patterns of Cenozoic Volcanism

A map compilation (1:1,000,000 scale) and supporting data have been assembled in order to study the distribution, age, petrographic characteristics and possible structural controls of Tertiary volcanic and igneous centers within the southern Basin Range Province. Although many of the volcanic centers in the study area have been previously mapped and discussed in published literature, recognition of regional patterns has not been emphasized. The use of ERTS-1 data for study of regional structural relationships has potential value in exploration for mineral resources or possible sources of geothermal energy known to be spatially associated with volcanic centers in the study area.

Regional Seismicity of the Southern Basin Range Province

A map compilation (1:1,000,000) of recorded earthquake epicenters and focal depths has been produced in order to study possible correlations of seismicity with regional structural patterns under investigation with the ERTS-1 imagery. Regional correlations have not been recognized for the distribution of earthquake magnitudes or focal depths because of the insufficient accuracy of this data. However, the map compilation documents the current activity of normal faulting in the southern Basin Range Province, and suggests that several systems of strike-slip faulting in the study area may also be presently active. Clustering of recorded earthquake epicenters generally parallels the trends of strike-slip fault systems in the Basin Range Province, and active seismicity appears to decrease with distance from these strike-slip systems. The coincident zone of strike-slip faulting and active seismicity along the western margin of the Basin Range Province is postulated to represent a major crustal discontinuity between the Sierra Nevada and the Basin Range Province.

D. Field Work Planned for Next Reporting Period

The following 2 months of this ERTS-1 investigation will be spent in preparation of the Type III Final Report. No additional field work is planned in support of this research.

A cooperative investigation is planned with Dr. Alexander Goetz, Jet Propulsion Laboratory, on discrimination of alteration/mineralization color anomalies using computer spectral ratioing techniques. This cooperative program will be continued upon receipt and processing of suitable ERTS-1 data.

E. Significant Results

The following abstracts are summarized from three Reports of Investigation accompanying this Progress Report. The reader is referred to these reports for more detailed discussions and documentation.

PAHRANAGAT SHEAR SYSTEM, LINCOLN COUNTY, NEVADA

Mark A. Liggett and Helmut E. Ehrenspeck

ABSTRACT

A structural model which relates strike-slip deformation to Basin Range extensional tectonics was formulated on the basis of analysis and interpretation of ERTS-1 MSS imagery over southern Lincoln County, Nevada. Study of published geologic data and field reconnaissance of key areas has been conducted to support the ERTS-1 data interpretation. The structural model suggests that a left-lateral strike-slip fault zone, called the Pahranagat Shear System, formed as a transform fault separating two areas of east-west structural extension.

FAULT PATTERN AT THE NORTHERN END OF THE DEATH VALLEY-FURNACE CREEK FAULT ZONE, CALIFORNIA AND NEVADA

An Application of ERTS-1 MSS Imagery

John F. Childs

ABSTRACT

The pattern of faulting associated with the termination of the Death Valley-Furnace Creek Fault Zone in northern Fish Lake Valley, Nevada was studied in ERTS-1 MSS color composite imagery and color IR U-2 photography. Imagery analysis was supported by field reconnaissance and low altitude aerial photography. The northwest-trending right-lateral Death Valley-Furnace Creek Fault Zone changes northward to a complex pattern of discontinuous dip-slip and strike-slip faults. This fault pattern terminates to the north against an east-northeast trending zone herein called the Montgomery Fault Zone. No evidence for continuation of the Death Valley-Furnace Creek Fault Zone is recognized north of the Montgomery Fault Zone. Penecontemporaneous displacement in the Death Valley-Furnace Creek Fault Zone, the complex transitional zone and the Montgomery Fault Zone suggests that the systems are genetically related.

Mercury mineralization appears to have been localized along faults recognizable in ERTS imagery within the transitional zone and the Montgomery Fault Zone.

STRUCTURAL LINEAMENTS IN THE SOUTHERN SIERRA NEVADA, CALIFORNIA

Mark A. Liggett and John F. Childs

ABSTRACT

Several lineaments observed in ERTS-1 MSS imagery over the southern Sierra Nevada of California have been studied in the field in an attempt to explain their geologic origins and significance. The lineaments are expressed topographically as alignments of linear valleys, elongate ridges, breaks in slope or combinations of these. The lineaments are typically less than one mile wide, and several can be traced in the ERTS-1 imagery for over 20 miles. Natural outcrop exposures along them are characteristically poor.

Two lineaments were found to align with foliated metamorphic roof pendants and septa within granitic country rock. Along other lineaments, the most consistent correlations were found to be alignments of diabase dikes of Cretaceous age and younger cataclastic shear zones and minor faults. Deep roadcut exposures in several key areas suggest that the dikes and planar shearing have controlled in-site weathering and erosion along the lineament trends. No evidence was found for hydrothermal alteration or Recent faulting along the lineaments. However, the location of several Pliocene and Pleistocene volcanic centers at or near lineament intersections suggest that the lineaments may represent zones of crustal weakness which have provided conduits for rising magma.

F. ERTS-1 Applications and Benefits

A variety of potential applications of ERTS-1 data are indicated by results of research summarized in this report. The following discussions are based on results from the current reporting period, and the reader is referred to the Argus Exploration Company Type II Progress Report of June 1973 for an evaluation of previous research findings.

Mineral Exploration

A detailed study has been conducted on the expression in ERTS-1 imagery of known mineral deposits in the southern Basin Range Province. The geologic features associated with these deposits include the following:

1. Regional structural setting
2. Lithologic associations
3. Alteration products, such as gossans, clays, etc.
4. Topographic expression of alteration emphasized by weathering and erosion
5. Local structural controls of ore deposition

Most of these characteristics are variable depending on the age, ore and alteration chemistry, and physiographic and climatic settings of the deposits. Nevertheless, the ability to conduct efficient reconnaissance using ERTS-1 MSS imagery provides a valuable basis for planning and guiding reconnaissance mineral exploration.

The spectral and spatial information in the ERTS-1 imagery are complementary to data from other conventional exploration techniques and not substitutes for them. These include reconnaissance geologic mapping, color aerial photography, airborne geophysics, and regional gravity surveys.

The value of ERTS-1 imagery for geological reconnaissance is documented in several studies conducted during this reporting period. A structural synthesis using ERTS-1 imagery over the northern portion of the Death Valley-Furnace Creek Fault Zone has revealed probable structural control of mercury mineralization associated with late Tertiary silicic volcanism (Childs, 1974). Similar regional associations of known gold mineralization with structurally controlled silicic volcanism is recognized in reconnaissance studies guided by ERTS-1 imagery in the volcanogenic provinces of southern Nye County, Nevada and along the Colorado River south of Lake

Mead (see Section IIIc).

High resolution false color compositing of the ERTS-1 MSS data (MacGalliard and Liggett, 1973) have proved to be a valuable tool for study of subtle alteration/mineralization color anomalies associated with known mining districts.

Potential Users:
- U. S. Geological Survey
- U. S. Bureau of Mines
- State geology and mining surveys
- Private exploration and mining companies
- Corresponding agencies in foreign countries

Geothermal Power Exploration

A number of known geothermal springs are aligned along structural lineaments under investigation in our ERTS-1 program. In most instances, insufficient evidence has been gathered to establish a genetic relationship between these structural features and the location of geothermal springs. However, most areas of known geothermal activity within the study area are closely associated with late Tertiary silicic volcanism and plutonism. The regional structural control of these volcanogenic provinces (see Section IIIc) provides a framework for discriminating areas of high potential for possible development of geothermal energy.

Potential Users:
- U. S. Geological Survey
- Private energy resource companies
- Public utility companies
- Corresponding agencies in foreign countries

Geologic Hazards Research

Several investigations conducted during this reporting period illustrate the effective application of ERTS-1 imagery for recognition and study of active fault systems.

ERTS-1 imagery was used in studying the complex pattern of faulting associated with the northern termination of the Death Valley-Furnace Creek Fault Zone in eastern California and western Nevada (Childs, 1974). Many of these faults displace alluvium of Quaternary or Recent age, and are considered currently active. A study of the relationship between strike-slip and normal faulting of late Quaternary or Recent age was conducted using ERTS-1 data over the Pahranagat Shear System of southern Lincoln County, Nevada (Liggett and Ehrenspeck, 1974).

On a more regional scale, our study of the distribution of recorded earthquake epicenters in the southern Basin Range Province (see Section IIIc) indicates a positive correlation between seismicity and major structural patterns apparent in the ERTS-1 data.

The use of ERTS-1 imagery for reconnaissance of active fault breaks, and study of regional structural patterns can have important applications in a variety of land use planning roles. These include the location and design of engineering projects, such as dams, nuclear generating plants, pipelines and highway systems.

Potential Users:
- U. S. Bureau of Land Management
- U. S. Bureau of Reclamation
- U. S. Atomic Energy Commission
- U. S. Department of Transportation
- Federal, state, and county land-use planning agencies
- U. S. Geological Survey
- Public utility companies

G. Authorized Reports and Presentations

Liggett, M.A. and Ehrenspeck, H.E., January 1974, Pahranagat Shear System, Lincoln County, Nevada: NASA Report of Investigation, 11 pp.

Childs, J.F., January 1974, Fault Pattern at the northern end of the Death Valley-Furnace Creek Fault Zone, California and Nevada. An Application of ERTS-1 MSS Imagery: NASA Report of Investigation, 10 pp.

Liggett, M.A. and Childs, J.F., January 1974, Structural lineaments in the southern Sierra Nevada, California: NASA Report of Investigation.

MacGalliard, W., and Liggett, M.A., November 1973, False-color compositing of ERTS-1 MSS imagery: NASA Report of Investigation, 5 pages.

Childs, John F., November 1973, A major normal fault in Esmeralda County, Nevada: in A reconnaissance space sensing investigation of crustal structure for a strip from the eastern Sierra Nevada to the Colorado Plateau, Type I Progress Report, pp. A1-A6.

Bechtold, I.C., Liggett, M.A., and Childs, J.F., October 1973, Remote sensing of faulting in alluvium, Lake Mead to Lake Havasu, California, Nevada and Arizona: in Geology, seismicity, and environmental impact, edited by D.E. Moran, J.E. Slosson, R.O. Stone, and C.A. Yelverton: Association of Engineering Geologists, Special Publications, pp. 157-161.

Articles

Batt, Leo, 7 December 1973, Subterranean conditions mapped by eye in the sky: Los Angeles Herald-Examiner, page A-10.

(This article discusses the NASA ERTS-1 program and practical applications of ERTS-1 data made by Argus Exploration Company in the study of geologic hazards and potential ground water sources related to the previously unmapped Pahrump Fault Zone of eastern California and southwestern Nevada.)

NASA Reports

Technical Reports:

10 September 1973
Type I Progress Report: 1 July through 31 August 1973
Ref: ERTS-1 Contract NAS5-21809

9 November 1973
Type I Progress Report: 1 September through 31 October 1973
Ref: ERTS-1 Contract NAS5-21809

Financial Reports

Argus Exploration Company billing:
NASA contract NAS5-21809
Form No. 1035

13 July 1973
15 August 1973
10 September 1973
10 October 1973
19 November 1973
17 December 1973

Monthly Contractor Financial Management Report
Form 533M

16 July 1973
15 August 1973
14 September 1973
24 October 1973
27 November 1973

Quarterly Contractor Financial Management Report
Form 533Q

16 July 1973
24 October 1973

IV. CONCLUSIONS

The research conducted during this reporting period has concentrated on a synthesis of data on a variety of geologic phenomena in the southern Basin Range Province. This work has established a basis for evaluation of applications of ERTS-1 MSS imagery to study of regional tectonics and related mineral, geothermal, and hydrological exploration and reconnaissance of structural geologic hazards.

The effective use of ERTS-1 imagery in these applications is based on the following characteristics, summarized in this and previous Argus Exploration Company reports:

1. The scale, resolution and spectral range of the ERTS-1 MSS imagery permits interpretation of subtle structural alignments over larger areas than feasible with conventional aerial imagery or geologic mapping. In this sense, the synoptic nature of the ERTS data provides an effective filter for studying regional geologic features, trends or patterns obscured by detail at the scale of an outcrop or quadrangle map.

2. The ability to interpret regional structural patterns and geologic correlations from ERTS-1 data provides a base for integration and synthesis of independent data, previously possible only with map compilations. Results of our research illustrate the value of this approach for understanding interrelationships of regional structure with volcanism, plutonism and related alteration, mineralization, and geothermal activity.

3. Field reconnaissance guided by ERTS-1 imagery is highly efficient, especially when aided by subsidiary remote sensing data of intermediate scale and resolution. Although anomalies in the ERTS imagery frequently have vague expression in the field, critical sites for detailed mapping or geophysical study can be determined, eliminating extensive ground-based reconnaissance required in conventional geologic mapping.

Several limitations in the effective use of ERTS-1 data result in part from inadequate analysis and interpretation techniques, and are not due to inadequacies of the primary MSS data. Examples include discrimination of rock or soil types, especially in vegetated terrain, and the study of structural features having high local variability. Such features as thrust faults, some with large surface exposures, have proved difficult to distinguish because of the irregular outcrop patterns. However, aerial remote sensing techniques, including SLAR, have not shown advantages over ERTS-1 data in these applications.

The use of satellite remote sensing does not outmode methods of classical field geology. Many of our investigations have relied heavily on data of previous studies which have involved laborious geologic or structural mapping, geochemical sampling

and analysis, petrography or geochronology. ERTS-1 data has provided new and complementary information in regional reconnaissance mapping or exploration. Refinements in data analysis and interpretation methods show promise for applications of satellite remote sensing to a broad range of geologic research problems, including operational resource exploration and management.

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